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COMPARISON OF MANUAL (GRAB) AND VACUUM TYPE AUTOMATIC SAMPLING TECHNIQUES ON AN INDIVIDUAL AND COMPOSITE SAMPLE BASIS

NATIONAL FIELD INVESTIGATIONS CENTER

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16. Abstracts

The National Field Investigations Center-Denver (NFIC-D) has been engaged in water quality and waste source evaluation studies since its inception. Due to the magnitude of the surveys, NFIC-D often has relied upon automatic samplers, particularly the SERCO, to collect samples of the wastewater streams. These samplers are used to collect water samples over specified periods for subsequent compositing; individual grab samples are collected manually. With the advent of compliance monitoring, the use of automatic samplers is expected to increase. Data provided by the manufacturer show that the automatic and manual sampling methods are equivalent. To confirm that the sampling methods are equivalent, NFIC-D conducted studies at a local wastewater treatment plant (WWTP) and statistically evaluated the results. This paper presents the results of these studies.

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ENVIRONMENTAL PROTECTION AGENCY
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COMPARISON OF MANUAL (GRAB) AND VACUUM TYPE AUTOMATIC SAMPLING TECHNIQUES ON AN INDIVIDUAL AND COMPOSITE SAMPLE BASIS

NATIONAL FIELD INVESTIGATIONS CENTER - DENVER
DENVER, COLORADO

SEPTEMBER 1974

DISCLAIMER

Mention of brand name of equipment does not constitute endorsement or recommendation of product by the Environmental Protection Agency. The information and findings presented in this paper are not to be construed as representing official equipment design or modification specifications.

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GLOSSARY

Composite Sample - Individual grab samples of fixed volume collected on a regular time basis and combined on the basis of the corresponding volume of flow at the time of collection.

Individual Grab Sample or Grab Sample - One sample of fixed volume collected either manually or by automatic sampler and analyzed independently.

TS - Total Solids

TSS - Total Suspended Solids

VSS - Volatile Suspended Solids

Statistical Parameters

μ = Population mean

σ = Population standard deviation

$\sigma_{\overline{X}}$ = Standard error of the population mean

$\overline{X}$ = Sample mean

S = Sample standard deviation

$S_{\overline{X}}$ = Standard error of the sample mean

I. INTRODUCTION

The National Field Investigations Center-Denver (NFIC-D) has been engaged in water quality and waste source evaluation studies since its inception. Due to the magnitude of the surveys, NFIC-D often has relied upon automatic samplers, particularly the SERCO, to collect samples of the wastewater streams. These samplers are used to collect water samples over specified periods for subsequent compositing; individual grab samples are collected manually.

With the advent of compliance monitoring, the use of automatic samplers is expected to increase. Data provided by the manufacturer show that the automatic and manual sampling methods are equivalent (Appendix). To confirm that the sampling methods are equivalent, NFIC-D conducted studies at a local wastewater treatment plant (WWTP) and statistically evaluated the results. This paper presents the results of these studies.

II. SUMMARY AND CONCLUSIONS

The SERCO automatic sampler was compared with the manual sampling method on a composite sample and individual grab sample basis on July 16-21, July 22-27, and August 15-22, 1974. Samples were collected from a local wastewater treatment plant and analyzed for total solids, total suspended solids and volatile suspended solids July 16-27, and for total suspended solids August 15-22; composite samples were combined on a flow weighted basis.

The statistical approach used to evaluate the data was the two-tailed "t" test at a risk level of 5% (95% confidence level). The pooled sum of squares method was used to calculate the statistical parameters. The hypothesis, tested statistically, was formulated: the mean of the samples collected by one sampling technique is equal to the mean of the samples collected by either a similar sampling technique or different sampling method. If the value of "t" calculated from the data was less than the tabular value of "t", the hypothesis was accepted.

The automatic sampler data were also compared with one another to determine if there was a significant difference in the samples when the probe inlets faced upstream downstream, or lateral to the direction of flow.

Although the samples were collected in locations where the wastewater was thoroughly mixed, the possibility existed that the solids could vary with depth. Since the automatic sampler collects samples at depth, and manual collection includes surface sampling, a special sampler

manually operated, was fabricated to collect samples at the same depth as the automatic sampler. Results were compared with results from the manual and automatic sampling methods.

The sampling frequency for a composite sample was evaluated also. Samples were collected manually at 15 and 60 minute intervals for 6 hours and composited individually.

Based on the statistical evaluation, the following conclusions were made:

EQUIVALENT ON A COMPOSITED SAMPLE BASIS

1. Automatic Sampler and Manual Sampling Method
2. Automatic Sampler and Special Sampler
3. Automatic Sampler and Automatic Sampler
4. Manual Sampling Method and Special Sampler
5. Manual 6-Hour Composite (15-minute interval) and Manual 6-Hour Composite (60-minute interval).
6. Automatic Sampler and Manual 6-Hour Composite (15 and 60-minute intervals).

EQUIVALENT ON AN INDIVIDUAL GRAB SAMPLE BASIS

1. Automatic Sampler and Automatic Sampler[a/]
2. Manual Sampling Method and Special Sampler

NOT EQUIVALENT ON AN INDIVIDUAL GRAB SAMPLE BASIS

1. Automatic Sampler and Manual Sampling Method
2. Automatic Sampler and Special Sampler

a/ The samples collected with the probes in the upstream and downstream positions were not equivalent only for the VSS parameter for the influent, July 16-21. Since the VSS parameter was considered unsatisfactory for the statistical comparison, it was concluded that all probe positions collected equivalent samples.

In the above comparisons, the automatic sampling method, with the probes facing in any position relative to the direction of flow, was equivalent to the other sampling methods, except on the individual grab basis. In the comparison of automatic sampler vs. automatic sampler, the position of the probe was not significant as samples were equivalent on a composite sample basis and grab sample basis.

The temperature of the first sample collected by the automatic sampler was monitored for six and ten hour periods. About six hours is required for the initial sample to cool from 21°C to 4°C. When the bottles and automatic sampler were cooled prior to the sampling period (i.e., overnight), the time required to cool the sample from 21°C to 4°C was only three hours. When the ambient air temperature is above freezing, the rate of temperature drop may be further increased by replacing the insulated metal box housing the sampler, with a non-insulated metal housing, and packing ice between the metal housing and an insulated outer box. This modification is currently being done by NFIC-D.

The results confirm that the vacuum type automatic sampler evaluated in this study may be used to collect representative wastewater samples on a composite basis. Modifications to the sampler are necessary to provide adequate sample preservation.

The findings also raise serious doubts as to the viability of accepted manual grab sampling methods, particularly with respect to high and variable solids collection. Therefore NFIC-D has initiated an ancillary testing program to develop reliable grab sampling equipment and techniques.

III. SERCO AUTOMATIC SAMPLER

The SERCO automatic grab sampler, Model NW-8, works on a vacuum principle. Twenty-four, 500 ml bottles are evacuated to approximately 25 inches of mercury by means of an AC operated vacuum pump. Each bottle is connected by an individual tygon tube or similar tubing to an intake probe which is immersed in the wastewater stream. Samples are collected when the mechanical triggers are activated sequentially using a clock and distributor arm assembly[a/]. As each trigger is activated, the vacuum on the respective sample bottle is released and a wastewater sample is drawn into the bottle.

The amount of the sample collected depends on the atmospheric pressure, the degree of evacuation, and the lift. After collection, the samples are hand composited on an equal volume or flow weighted basis. The sampler is readied for the next compositing period by back-flushing the collection lines with tap water and inserting clean bottles.

The sampler is housed in a metal case. The 24 bottles encircle two plastic ice containers used to preserve samples. NFIC-D has modified the unit for summer and winter application. The entire unit is placed in a foam insulated plywood box. For warm weather use, additional ice is packed between the metal case and plywood box to increase the rate of temperature decrease and to help maintain low sample temperatures. During cold weather conditions, a heat source (light bulb), which is controlled by a thermostat, is placed inside the plywood box to prevent the clock, mechanical parts, and samples from freezing. The heat source operates with either AC or DC power.

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a/ Triggers can be activated at various intervals, usually 5, 15 or 60 minute, depending upon the clock used.

The sampler has proved mechanically reliable under extensive use by NFIC-D field personnel. Operational difficulties are minimal and only routine maintenance is required.

A more detailed description of the SERCO automatic sampler is presented in the appendix.

IV. FIELD STUDY PROCEDURE

A local wastewater treatment plant was selected for the study due to its proximity to the NFIC-D laboratories and reliable flow measuring equipment. The study was conducted over three periods, July 16-21, July 22-27, and August 15-22, 1974.

A. Parameters Evaluated

Total solids (TS), total suspended solids (TSS), and volatile suspended solids (VSS) were evaluated for the July studies. The only parameter used in the August study was TSS since most NPDES permits limit suspended solids rather than TS and VSS. Analyses were done according to Methods for Chemical Analysis of Water and Wastes, EPA, NERC-AQC Laboratory, Cincinnati, Ohio, July 1971, as specified in the October 16, 1973 issue of the Federal Register, "Guidelines Establishing Test Procedures for Analysis of Pollutants".

Field measurements of pH and temperature were made as samples were collected. Flows were determined from a Parshall flume and recording device. During the July study a thermocouple probe was placed inside an automatic sampler bottle containing the first sample collected and the rate of temperature decrease was monitored.

B. Sampling Methods

To minimize the variations in the data during the evaluation of manual and automatic sampling methods, samples were collected simultaneously. The trigger mechanisms on the automatic samplers were tripped by hand at the same time that manual samples were collected. All composite samples were manually combined on a flow weighted basis at the end of

the sampling period. Dye was added periodically at the influent to the grit chamber to insure that the wastestream was mixed thoroughly at the sampling location downstream from the grit chamber. Dye was also added periodically in the final clarifier overflow to the wet-well to determine that adequate mixing occurred at this sampling location. All samples were preserved under ice and analyzed within two hours at the laboratory.

Automatic samplers were compared with the manual sampling method on an individual grab sample basis and a composite basis.

July 16-21 (Influent)

Three automatic samplers were placed at the plant influent, each with a sampling probe inlet facing in a different position, e.g., upstream, downstream, and lateral (perpendicular), to the direction of flow. Samples were collected hourly for 12 hours with the automatic samplers and by the manual sampling method and composited at the end of each 6-hour period, yielding 2 sets of composite samples per sampling technique daily. In addition, two 6-hour composites, composed of 24 manually collected samples (15-minute intervals) were collected sequentially over the 12-hour period to determine if a significant difference existed as a result of the sample collection frequency at random intervals.

Six individual grab samples were collected by each sampling technique during the 12-hour period.

July 22-27 (Influent and Effluent)

The automatic sampler probes were placed in the influent and effluent in the lateral position only, since under many field conditions, this

is the only position available due to the limitations of the probe length and the configuration of the sampling location. Samples were collected hourly using automatic and manual sampling techniques. These samples were composited at the end of 24 hours.

Six individual grab samples, each from the influent and effluent, were collected randomly over 24 hours using both sampling techniques.

August 15-22 (Effluent)

Four automatic samplers were placed at the effluent wet-well. Two sampling probes were placed with the intakes facing upstream and two probes were placed in a lateral position. All probes were positioned at the same depth. Samples were collected for 12 hours at 1-hour intervals and composited at the end of each 6-hour interval, providing 8 composite samples daily. In addition, four random grab samples were collected daily with each automatic sampler.

Grab samples were collected manually at the same time that the automatic samplers collected samples and composited in the same manner. Manual grab samples were also collected for individual analysis at the same times as the automatically collected samples.

Although the samples were collected at locations where the wastewater was thoroughly mixed, the possibility existed that the solids could vary with depth. Because the automatic sampler probe is immersed in the wastewater stream and manual sampling normally includes surface flow as well as the flow at depth, a special sampler was built to obtain a grab sample at the same depth as the automatic sampler probe.

A 500 ml sample bottle was attached to a metal pole; a rubber stopper, mounted on a tripping rod, sealed the bottle until it reached the desired depth at which time the stopper was removed, the sample collected, and the stopper was replaced. Composite and grab samples were collected with the special sampler at the same times that the automatic and manual samples were taken.

V. STATISTICAL APPROACH

A. Parameters

Since the entire wastewater stream could not be examined to determine actual values of the statistical parameters, estimators were used to evaluate a given parameter. For example, the sample mean $\overline{X}$ is an estimator for the population mean μ, and the estimator for σ, the standard deviation of the population distribution, is S. When making inferences based on estimators, it is necessary to obtain estimates for the variances of the estimators. In the case of the sample mean, the variance is $\sigma_{\overline{X}}^2 = \sigma^2/n$ where n is the sample size. To estimate the variance, $S_{\overline{X}}^2 = S^2/n$ is substituted. The standard error of the mean $\sigma_{\overline{X}}$ is estimated by $S_{\overline{X}}$.

B. "t" Test

The "t" distribution was used to test the hypothesis that the mean of the samples collected by one method is equal to the mean of the samples collected by another method, e.g., composite sample made up of individual hand grab samples vs composite made from samples collected by an automatic sampler.

The t-distributions are a one-parameter family of distributions. The distributions vary with the size of the sample and the effect of sample size is evaluated in terms of degrees of freedom. The distribution is symmetric with the mean equal to zero, but for finite degrees of freedom, it differs from the normal distribution in that there is more area in the tails of the t-distribution and it is more peaked. As the degrees of freedom increase (i.e., more samples), the more closely the t-distribution resembles the normal distribution.

If the sample size, n, is small (less than 30), the "t"-test is used, even if the samples are from populations which depart "moderately" from normal populations (1). The value of "t" is calculated from the equation

$$t = \frac{|\bar{X}-\mu|\sqrt{n}}{s}$$

Special tables list the value "t" may reach for given probability levels, and the calculated "t" may be compared with the tabular value to determine if the hypothesis is valid. If the absolute value of the calculated "t" is less than the tabular value, the hypothesis is acceptable.

C. Two Sample Techniques

If two independent random samples, one from each of two populations are collected, the pooled technique may be used to estimate the variance in the "t" test. Since the two independent random samples came from the same wastewater stream, the variance, σ^2, and mean, μ, are assumed to be the same for both populations and the best estimate is obtained by pooling the information contained in both samples.

The "t" statistic is then calculated as follows:

$$t = \frac{(\bar{X}_1-\bar{X}_2) - (\mu_1 - \mu_2)}{Sp\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where Sp is the pooled variance estimator and the degrees of freedom equal to $n_1 + n_2 - 2$. Since μ_1 is equal to μ_2, $t = \frac{\bar{X}_1-\bar{X}_2}{Sp\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$

The calculated value is compared with the tabular value to determine if the hypothesis that the means are equal is true. For this study, a risk level of 5% was selected (95% confidence level).

(1) Wieks, S.S., Elementary Statistical Analyses, Princeton University Press. Princeton, New Jersey, 1958.

VI. STATISTICAL ANALYSIS OF DATA

The statistical hypothesis, the mean of the samples collected by one sampling technique is equal to the mean of the samples collected by either a similar sampling technique or different sampling method, was formulated and evaluated at the 95% confidence level. The hypothesis was tested using the "t" distribution, and the pooled sum of squares method was used for calculating the statistical estimators. If the value of "t" calculated from the data was less than the tabular value for "t", the hypothesis was accepted. A 2-tail test was used and the $\alpha/2$ value was 0.025. The degrees of freedom were dependent on sample size.

A. Significance of the Automatic Sampler Probe Position

1. July 16-21 Sampling Period - The automatic sampler probes were placed in the influent with the inlets facing upstream, downstream, and laterally to the direction of flow. Samples were collected for evaluation on an individual grab basis and a 6-hour composite basis for 6 days. Thirty-six samples were collected for the grab basis evaluation and twelve samples were collected for the composite basis evaluation (Table VI-1).

Based on the 6-hour composite samples, the statistical analysis showed that the automatic samplers collected equivalent samples for the three probe positions for all three parameters.

The same results were obtained on the grab sample basis evaluation for all probe positions for TS and TSS. However, for the VSS parameter, the samples collected with the probes in the upstream and lateral positions were not equivalent. The upstream vs downstream and downstream vs lateral samples were statistically equal.

TABLE VI-1

COMPARISON OF SAMPLING METHODS
WWTP INFLUENT
July 16-21, 1974

Sampling Technique	Grab Samples N[a/]=36						6-Hour Composite Samples N=12					
	TS (mg/l)		TSS (mg/l)		VSS (mg/l)		TS (mg/l)		TSS (mg/l)		VSS (mg/l)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Automatic Sampler												
Upstream[b/]	533-741	641	26-240	126	22-108	110	581-965	662	92-182	118	72-146	100
Downstream	554-742	650	24-292	133	18-278	116	588-690	642	92-180	125	70-170	111
Lateral	548-774	660	12-324	155	8-314	139	580-728	650	80-230	136	74-212	123
Manual Sample												
60 minute[c/]	525-730	620	10-224	108	6-210	94	595-653	627	86-156	112	82-144	101
15 minute	-	-	-	-	-	-	525-730	620	56-174	121	34-150	103

a/N is the number of samples.
b/Indicates probe inlet position relative to the direction of flow.
c/Indicates the elapsed time between sample collection.

2. August 15-22 Sampling Period - Four automatic samplers were used to collect the effluent, two probes were placed with the inlet facing in the upstream position (UP-1 and UP-2) and two with the inlet facing laterally (LAT-1 and LAT-2) to the direction of flow. The sampling duration was 12 hours per day over the 7-day period, however samples were composited after the first six hours and after the second six hours for a total of 14 samples per automatic sampler. Twenty-eight individual grab samples were also collected at random with each sampler during the 7 days for a comparison on an individual grab sample basis.

The following comparisons were made of the automatic samplers for both composite and the individual grab samples collected over the 12 hour daily sampling period (Table VI-2).

a) UP-1 vs UP-2 and LAT-1 vs LAT-2 to determine if two samplers with probes placed in the same direction collected equivalent samples, and

b) Upstream position vs lateral position to determine the effect of probe position on sample collection.

The statistical analysis showed that the samplers were equivalent for all comparisons.

The same comparisons, a) and b), were also made using the individual 6-hour composites collected during the first and second 6-hour intervals over the 12-hour sampling period (Table VI-3). The statistical analysis again showed that samplers were equivalent for all comparisons.

TABLE VI-2

COMPARISON OF SAMPLING METHODS
TOTAL SUSPENDED SOLIDS
WWTP EFFLUENT
August 15-22, 1974

Sampling Technique	Grab Samples N[a/] = 28 Range (mg/l)	Grab Samples N[a/] = 28 Mean (mg/l)	6-Hour Composite Samples N=14 Range (mg/l	6-Hour Composite Samples N=14 Mean (mg/l)
Automatic Sampler				
Upstream[b/]-1[c/]	10-45	25	16-48	28
Upstream-2[c/]	10-61	26	14-55	30
Lateral-1	9-66	29	8-41	26
Lateral-2	9-42	26	11-59	30
Manual Sample	6-32	21	19-67	30
Special Sampler[d/]	4-39	21	9-39	23

a/N is the number of samples.
b/Indicates probe inlet position relative to the direction of flow.
c/Indicates either first or second sampler.
d/Special sampler collected samples from the same depth as the automatic samplers. Sampler was manually operated.

TABLE VI-3

COMPARISON OF SAMPLING METHODS
INDIVIDUAL SIX-HOUR COMPOSITE SAMPLES
TWELVE HOUR STUDY PERIOD
TOTAL SUSPENDED SOLIDS (mg/l)
WWTP EFFLUENT
August 15-22, 1974

	Automatic Sampler											
	Upstream[a/]-1[b/]		Upstream-2[b/]		Lateral-1		Lateral-2		Manual Sample		Special Sampler[c/]	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
First Six Hour Period	16-48	27	14-55	30	8-41	23	11-59	26	19-67	32	9-37	21
Second Six Hour Period	21-39	29	16-50	30	21-37	30	22-40	33	20-37	28	15-39	26

a/ Indicates probe inlet position relative to the direction of flow.
b/ Indicates either first or second sampler.
c/ Special sampler collected samples from same depth as the automatic samplers. Sampler was manually operated.
Note: Number of samples collected by each method was 7.

B. Comparison of Automatic Sampler vs Manual Sample Method

1. July 16-21 Sampling Period - Manual samples were collected according to established procedures. The discrete manual samples were collected using a fixed volume dipper (stainless steel) attached to a metal pole. The dipper was rinsed several times in the wastestream before the sample was taken. The samples were placed in 500 ml bottles and stored at 4°C. .

The manual sampling technique was compared with the automatic sampling technique with the probes placed in the three different positions (Table VI-1). Based on the 6-hour composite samples, samples collected manually were equal to the samples collected with the automatic samplers. On an individual grab sample basis however, the manual sampling method was not equivalent to the automatic sampling method for the lateral and downstream probe positions, but was equivalent when the probe was in the upstream position.

2. July 22-27 Sampling Period - Manual and automatic sampling techniques were compared on the wastewater treatment plant influent and effluent (Table VI-4). The automatic sampler probes were placed in the lateral position only. Samples were composited over 24 hours.

On the 24-hour composite basis for the influent samples, the automatic sampling and the manual sampling methods were equivalent only for the total solids parameter. The two sampling techniques were statistically equivalent for the effluent samples for TS, TSS, and VSS.

TABLE VI-4

COMPARISON OF SAMPLING METHODS
WWTP INFLUENT AND EFFLUENT
July 22-27, 1974

Sampling Technique	Influent						Effluent					
	TS (mg/l)		TSS (mg/l)		VSS (mg/l)		TS (mg/l)		TSS (mg/l)		VSS (mg/l)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
24-Hour Composite[a]												
Automatic Sampler[b]	573-720	629	106-178	143	86-158	122	481-510	497	12-26	22	12-30	20
Manual Sample	574-640	607	81-120	93	68-106	81	442-514	498	16-139	45	16-105	37
Grab Sample[c]												
Automatic Sampler[b]	493-776	649	25-350	138	21-324	122	459-539	507	13-52	26	10-42	23
Manual Sample	446-712	602	7-328	88	7-274	78	456-537	502	4-42	20	4-42	19

a/ Sample size = 6
b/ Sampler probe inlet in the lateral position relative to the direction of flow.
c/ Sample size = 35 for the influent and 36 for the effluent.

On an individual grab basis, the two methods were not equivalent for total suspended and volatile suspended solids for either the influent or the effluent samples. For the total solids parameter, the sampling methods were equivalent for the effluent, but not for the influent.

3. August 15-22 Sampling Period - Based on the 6-hour composite samples, the sample collected with the automatic samplers with the probes in the upstream and lateral positions were equal to the samples collected manually (Table VI-3).

On the individual grab sample basis, the automatic sampling and manual sampling methods were not equivalent.

C. Comparison of Manual Sample Method and Special Sampler

Since the analysis of the data for the July studies showed that the automatic samplers were not equivalent to the manual sampling method on an individual grab sample basis, a special sampler was fabricated to collect samples at the same depth as the automatic sampler probes (Section IV). The special sampler, operated manually, was used during August 15-22.

The samples collected by the manual method were statistically equal to the samples collected by the special sampler for the individual grab samples and the 6-hour composite samples (Table VI-2).

D. Comparison of Automatic Sampler and Special Sampler

Based on the 6-hour composite samples, the automatic sampler and special sampler collected equivalent samples (Table VI-2). However, the methods were not equivalent on the individual grab sample basis.

E. Composite Sample Collection Frequency (July 16-21)

Manual samples were collected hourly and every 15 minutes for 6 hours and composited into two separate samples to determine if there was a significant difference in sampling frequency (Table VI-1). The frequency of sample collection was insignificant as the samples collected at each time interval were equal.

The samples collected manually every 15 minutes and composited after 6 hours were also compared with the automatic sampler 6-hour composited samples which were collected hourly. The former samples were equal to the automatic sampler composites for all three probe positions, upstream, downstream, and lateral.

VII. ADDITIONAL DATA EVALUATION

A. Sampling Velocities of Automatic Samplers

The relative intake sampling velocities of the automatic samplers were measured for the period July 16-21. The tubing lengths from the probe inlet to the top of the automatic sampler were marked at exactly 8.0 feet; the elapsed time between the tripping of the mechanical trigger, releasing the vacuum, and the sample reaching the 8 foot mark was 1.0 second. The vacuum in the bottles was approximately 21 inches of mercury. The lift was 8 feet and the barometric pressures ranged from 24.69 to 24.99 inches of mercury.

All of the automatic samplers had relative velocities of 8 feet per second for a total of 34 observations. Since a greater vacuum can be exerted at lower elevations, the velocities may increase. An increase in velocity or vacuum would result in an increase in the amount of sample collected.

B. Temperature Control in the Automatic Sampler (July 16-27)

The temperature inside the sample bottle containing the first sample collected was monitored to determine the rate of temperature decrease. The ambient air temperatures ranged from 27°C to 34°C (80°F to 93°F) during the study. The temperatures were monitored for 6 hours during the July 16-21 period when the 6-hour composites were collected and monitored for 10 hours during the July 22-27 period when the samples were composited over a 24-hour period (Figures VII-1 and VII-2).

FIGURE VII-1

AVERAGE TEMPERATURE DECREASE
AUTOMATIC SAMPLER BOTTLE
WWTP INFLUENT
6 HOUR COMPOSITE
JULY 16-21, 1974

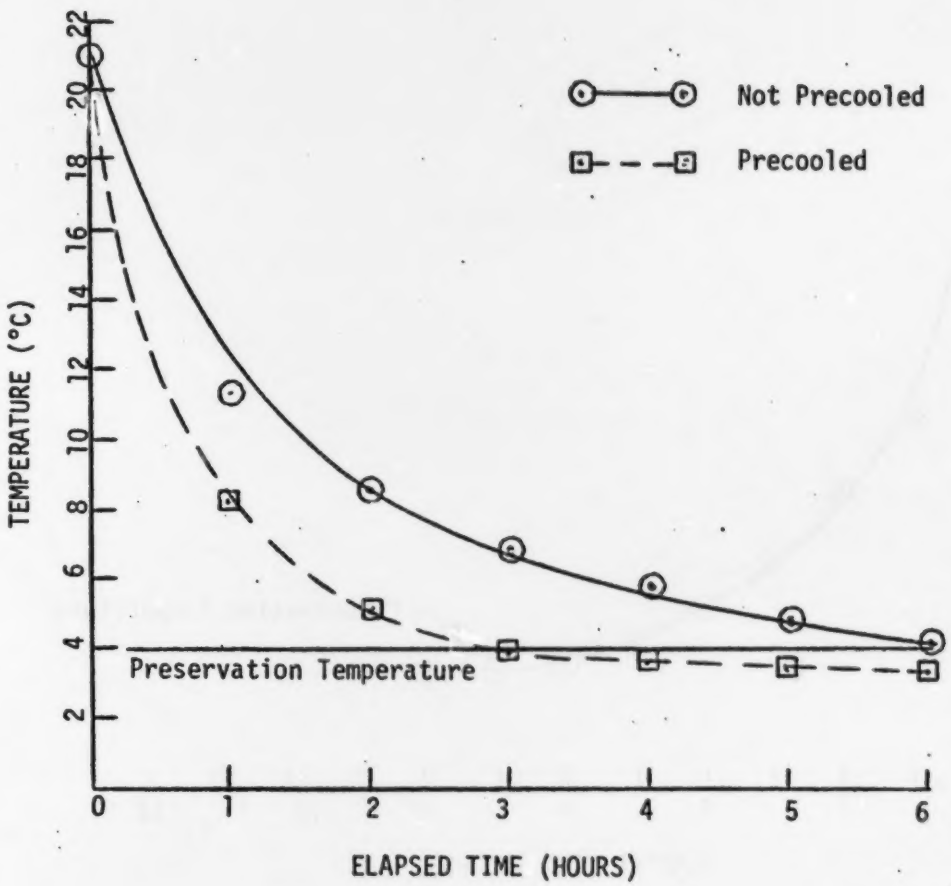
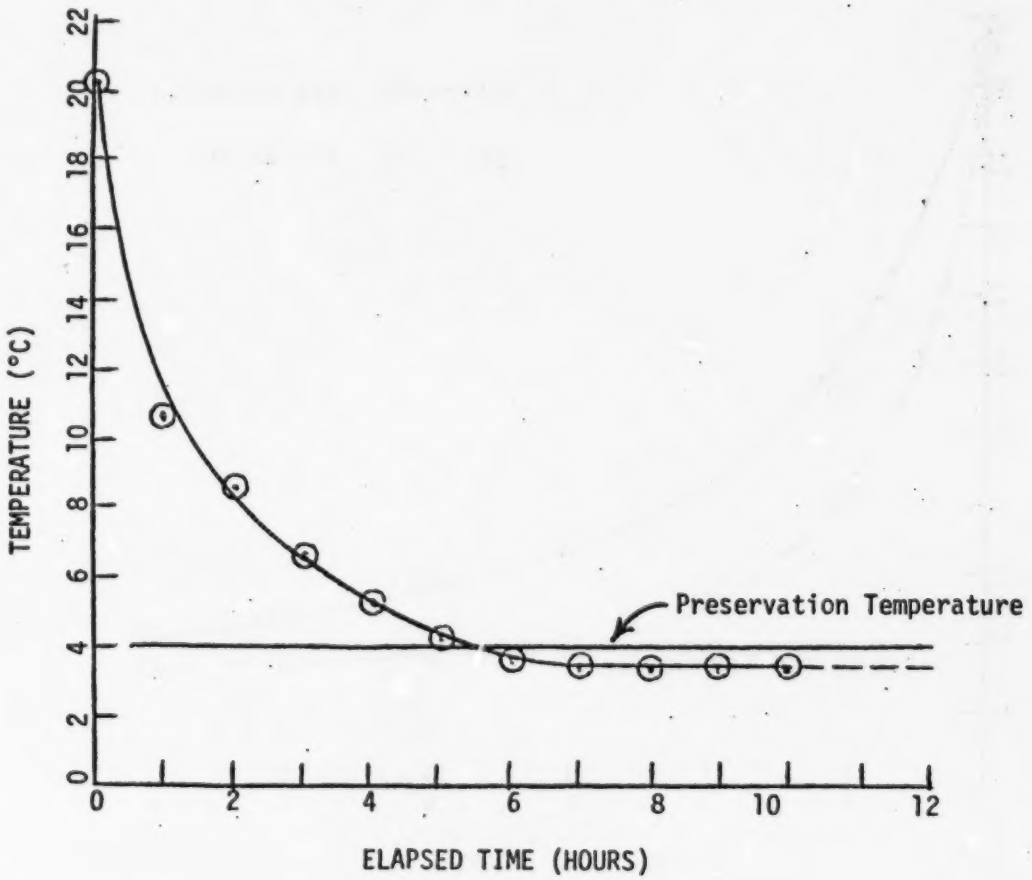


FIGURE VII-2

AVERAGE TEMPERATURE DECREASE
AUTOMATIC SAMPLER BOTTLES
WWTP INFLUENT
24 HOUR COMPOSITE
JULY 22-27, 1974



After collection it required approximately 6 hours for the samples to reach 4°C from 21°C when precooling of the sampler was not practiced. Whe precooling was employed, i.e., the automatic samplers were left overnight in their plywood boxes which were filled with ice, the temperature inside the sample bottle containing the first sample collected dropped from 21°C to 4°C in approximately 3 hours, or one-half the time required without precooling.

Temperatures of the first 6 individual samples, collected hourly, at the time of composition are listed in Table VII-1.

TABLE VII-1

TEMPERATURE OF INDIVIDUAL SAMPLES
AUTOMATIC SAMPLER

JULY 16-21, 1974

Bottle No.	Initial Temp °C	Time Elapsed Since Collection Hours	Temperature (°C) When Removed From Sampler	Temperature Decrease, °C
1	21	5	4.9	16.1
2	21	4	7.0	14
3	21	3	9.5	11.5
4	21	2	11.8	9.2
5	21	1	16.8	4.2
6	21	0	21	0.0

VIII. DISCUSSION

The analytical techniques of the NFIC-D laboratory were checked on duplicate samples during the study. The reproducibility of the laboratory was 98.9%. The means of the samples and standard deviations were as follows.

	Mean (mg/l)	Standard Deviation (mg/l)
Total Solids	526	8.71
Total Suspended Solids	33	5.71
Volatile Suspended Solids	32	5.30

The analytical techniques were assumed insignificant in the statistical analysis since the reproducibility was very high and the variations of the solids were high. In addition, the samples used for comparison were analyzed at the same time and the laboratory techniques would be equivalent.

The statistical analysis of the sampling techniques showed that the automatic samplers were equivalent to the manual sampling method on a composite sample basis, but not on an individual grab sample basis. Although the July 22-27 study showed that the automatic and manual sampling techniques were equivalent for only total solids on the raw waste based on the 24-hour composite, the previous week's study showed that TS, TSS, and VSS were equivalent in the 6-hour composite samples. Since more samples were collected the first week, using three probe positions, and since only the lateral position was evaluated the second week, it was concluded that insufficent samples (6) were collected and that the July 16-21 sampling period was more representative of the automatic sampler performance.

Although the automatic sampler can be used to collect grab samples by installing a clock which activates the trigger mechanism at desired times, the practice at NFIC-D is to collect grab samples manually and use the automatic sampler for composite samples.

The data show that the samples collected manually were lower in concentration than the samples collected automatically (Tables VI-1, 2, and 4) on an individual grab basis. However, it cannot be concluded from this study that the automatic sampler does not collect a representative sample. In order to determine whether the automatically collected sample or the manually collected sample represents the true conditions of the wastewater stream requires that the parameters of the wastewater stream be known. This type of study necessitates a synthetic wastewater which can be rigorously controlled.

Ideally both methods should be compared using "isokinetic" sampling conditions. In field application, this is not practical or achievable to date. Manual sampling collects samples without exerting a velocity on the stream and the sampling velocity of the automatic sampler is dependent on the vacuum, lift, and barometric pressure, not on the flow rate.

The automatic samplers collected equivalent samples for the three positions on both the composite and grab sample basis, with one exception. The upstream vs the lateral positions were not equivalent for the VSS parameter during July 16-21 on an individual grab sample basis. However, the upstream position was statistically equal to the downstream position and the downstream position was equal to the lateral position for VSS. In the analysis for VSS, inorganic material will also be volatilized in the muffle

furnace along with the organic matter. The VSS are also more variable in the influent than in the effluent. Therefore it was concluded that VSS is not a satisfactory parameter for the statistical comparison. The possibility exists that the VSS for the upstream position may have been equivalent to the lateral position and statistically rejected (value of "t" calculated was 2.04 and the tabular value was 1.997), especially since the upstream vs downstream and downstream vs lateral were equivalent. The possibility also exists of accepting a hypothesis when it is false. However, the level of significance is selected to minimize the latter possibility. In this study, the level of significance, α, was 0.05, and the probability is much higher that a true hypothesis will be rejected than a false hypothesis accepted. Since the August 15-22 data showed that the probe locations, upstream vs lateral, were equivalent, and due to the other factors cited above, it was concluded that all probe locations collected statistically equivalent samples.

Since all probe positions collect equivalent samples on both a composite and grab sample basis, field application is not limited due to the configuration of the sampling site or height of the lift. Also, the probe can be positioned laterally or downstream position in the flow to prevent clogging or freezing of the inlet.

Sample collection frequency, on a composite basis, over a 6-hour period was not significant as the samples collected every 15 minutes and composited were equivalent to samples collected hourly and composited. The application of sampling more frequently is recommended when the wastewater stream is highly variable in strength. However, the length of sampling period would then be limited by the number of sample bottles.

The monitoring of temperature in the sample bottles clearly shows that the bottles should be precooled before sampling begins. NFIC-D is presently modifying the metal sampler case. A non-insulated case (thin walled, sheet metal) will be used when ambient air temperatures are above freezing. This casing will be used in the plywood box and ice packed between the metal and insulated plywood walls. It is expected that the temperature inside the sample bottles will decrease at a greater rate, thus enhancing sample preservation.

APPENDICES

SONFORD PRODUCTS CORPORATION

2155 RAND TOWER

MINNEAPOLIS 3, MINNESOTA

SERCO Automatic Sampler
Technical Report

The SERCO Automatic Sampler operates on the principle of Boyle's Gas Law. The sample is collected in the sampling container by a driving force caused by the difference in pressure in the evacuated container and the atmospheric pressure.

The size of sample collected depends on the atmospheric pressure, the level of evacuation, the lift, and the volume of the sampling container. The standard SERCO Sampler, Model NW-3, has a 16 oz. sampling container and three foot lift.

Sample Volume

The volume of sample to expect at various conditions is shown in Figure 1 and 2, as well as in the table in the brochure.

In general, the larger the volume of sample collected, the more representative it will be. According to Standard Methods for the Examination of Water and Waste Water, each individual waste water sample collected for compositing should be at least 120 milliliters and the portions should be collected each hour--in some cases each half hour or even every 5 minutes--and mixed at the end of the sampling period or combined in a single bottle as collected. This minimum is noted on the two figures and is recommended as the minimum volume of waste water to collect. Smaller volumes can be considered for special applications, however.

Larger sample volumes will be necessary for stream sampling because each individual sample will be analyzed. It is expected that about one liter (1000 milliliters) would normally be desired.

The volume of sample needed for other automatic sampling applications, such as river sediment studies and chemical processing control would be dictated by the specific needs of the applications.

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2355 Rand Tower
Minneapolis, Minnesota 55402

SAMPLING DATA

The following laboratory and field tests represent comparative analytical data of samples taken at the same time by the SERCO Automatic Sampler and manually for several different types of waste water. The comparison of sampler data with data for manually collected samples does not mean that it is assumed that manual sampling is more accurate. In fact, the samples collected with the Sampler may be more representative of conditions in the flowing stream. However, manual collection of samples is common in the waste water field and these studies have been made to demonstrate that the SERCO Automatic Sampler can collect at least as representative a sample as would be collected manually.

I. ACTIVATED SLUDGE

Several samples of activated sludge were collected directly from an aeration tank to determine the effect of the air bubbles in the liquid on the sampler, as well as its ability to collect the solids. The results of the analysis are as follows:

	Suspended Solids, mg/l	
Trial No.	SERCO Automatic Sampler	Manual
1	2585	2585
2	2650	2735
3	2790	2880
4	2950	2835
Average	2744	2759

Results of tests on concentrated activated sludge is as follows:

	Suspended Solids, mg/l	
Trial No.	SERCO AUTOMATIC Sampler	Manual
1	17,490	18,040
2	16,750	17,410
3	17,530	18,960
4	17,360	17,350
Average	17,540	17,940

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II. DOMESTIC WASTE

Laboratory Test

Fresh raw domestic waste was brought to the laboratory for this study. While the waste was being thoroughly mixed, nine samples were collected from the waste sample container with the SERCO Automatic Sampler and then were collected manually with 250 ml french-square bottles. The samples were collected alternately; that is, a sample was collected with the Sampler, then a sample was collected manually, and so on. The raw waste was thoroughly mixed using two plunger type manual mixers. These samples were analyzed for suspended solids and the data is as follows:

	Suspended Solids, mg/l	
Trial No.	SERCO Automatic Sampler	Manual
1	270	286
2	264	270
3	268	270
4	260	244
5	262	262
6	252	248
7	254	274
8	238	228
9	258	240
Range	238-270	228-286
Average	258.3	258.0

Field Studies

A SERCO Automatic Sampler was taken to a municipal waste treatment plant and 24 individual samples of the raw sewage were collected using the Sampler and 24 samples were collected manually at the same time. These samples were collected over a period of about 30 minutes. The two sets of 24 samples were composited separately and analyzed. The laboratory results are as follows:

Analysis	SERCO Automatic Sampler	Manual
5-day BOD, mg/l	72	72
Total solids, mg/l	2230	2270
Total volatile solids, mg/l	510	575
Suspended solids, mg/l	112	113
Suspended volatile solids, mg/l	103	104
pH	7.70	7.70

The above data demonstrates the ability of the SERCO Automatic Sampler to collect a representative sample of raw domestic sewage.

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III. MEAT PACKING WASTE

Composited samples of meat packing waste were collected using the SERCO Automatic Sampler and by manual procedures over the same 24 hour period. A total of 24 individual samples were collected at one hour intervals with the Sampler. The manual samples were collected at 30 minute intervals. The Sampler samples were collected from the influent channel, ahead of the Parshall flume. The manual samples were collected after the flume, as the waste water discharges into the wetwell. However, the same waste flow was collected at each location. The five day BOD results of the composited samples are as follows:

Analysis	SERCO Automatic Sampler	Manual
5-day BOD, mg/l	2095	2095
pH	7.10	7.10

Waste water samples were collected with the Sampler and manually from a combined domestic waste and meat packing waste. The meat packing waste constitutes about 90% of the waste water volume. The samples were collected manually and with the Sampler at exactly the same time from the influent channel to the primary settling tank. The analysis of the related samples are as follows:

	SAMPLER		MANUAL	
Sample No.	5-day BOD mg/l	Total Solids mg/l	5-day BOD mg/l	Total Solids mg/l
1	3280	6170	3300	6330
2	2790	5590	2670	5590
3	--	3590	--	3740
4	--	3790	--	3560
5	1900	3950	1620	3730
6	--	3820	--	3810
7	2050	4370	1750	4370
8	--	4330	--	4440
Average	2505	4450	2335	4446

Based on previous analytical data, the suspended solids concentration of the above sample would be expected to be 1000-1500 mg/l. The BOD and solids data indicates that the SERCO Automatic Sampler will collect representative samples of meat packing waste with high concentrations of organic solids. The total solids data showed almost identical analytical results and the BOD data was within the limits of accuracy for the test. It should be noted also, that the BOD of the manual samples were slightly lower.

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IV. PAPER MILL WASTE

Samples of paper mill waste water were collected both manually and with the SERCO Automatic Sampler at the same time. The analysis of samples of the screened wood room effluent are as follows:

	Analysis for Total Solids, mg/l	
Trial No.	SERCO Automatic Sampler	Manual
1	3600	2360
2	2560	3290
3	2820	2560
Average	2990	2680

The analysis of waste water from the Kraft Mill process is as follows:

Analysis for Total Solids, mg/l	
SERCO Automatic Sampler	Manual
710	725

The suspended solids concentration for the screened wood room effluent was about 2000 mg/l and for the Kraft Mill waste was about 100 mg/l. The sampling station used for the wood room effluent was located very close to the screens, making it difficult to obtain a uniform sample, which accounts for the variations in the solids concentration for both methods. The average concentration of solids for the wood roof effluent was higher in the samples taken with the Sampler because they were collected near the bottom of the channel, while the manual samples were collected near mid-depth. It is difficult to say which of the sampling methods is more representative of stream conditions. However, this test does clearly show that the SERCO Automatic Sampler can collect satisfactory samples of paper mill waste water with suspended solids concentrations of at least 2000 mg/l.

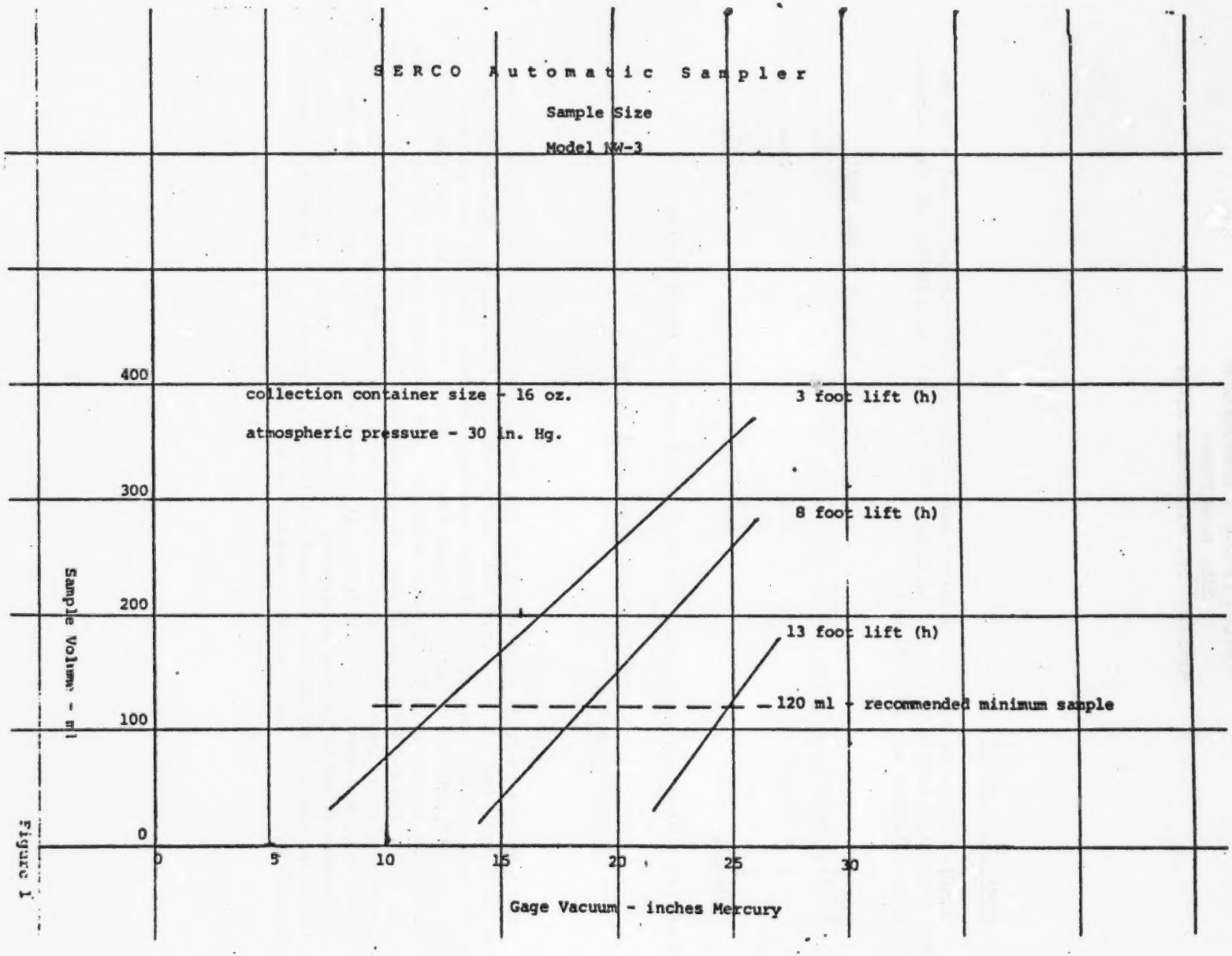

SERCO Automatic Sampler
Sample Size
Model NW-3
collection container size - 16 oz.
atmospheric pressure - 30 in. Hg.
3 foot lift (h)
8 foot lift (h)
13 foot lift (h)
120 ml - recommended minimum sample
Sample Volume - ml
400
300
200
100
0
0
5
10
15
20
25
30
Gage Vacuum - inches Mercury

Figure 1

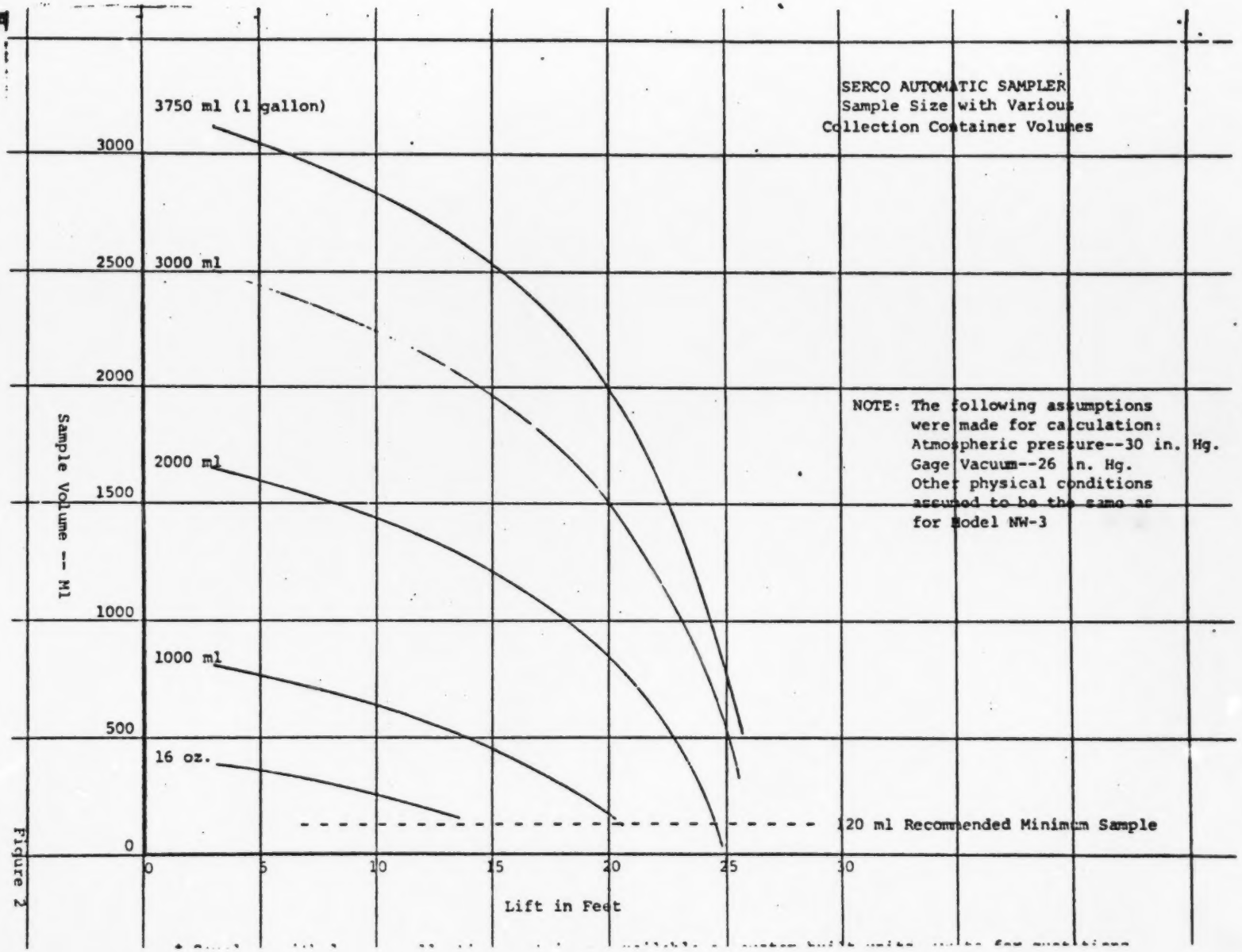

SERCO AUTOMATIC SAMPLER
Sample Size with Various
Collection Container Volumes
3750 ml (1 gallon)
3000 ml
2000 ml
1000 ml
16 oz.
120 ml Recommended Minimum Sample
NOTE: The following assumptions were made for calculation:
Atmospheric pressure--30 in. Hg.
Gage Vacuum--26 in. Hg.
Other physical conditions assumed to be the same as for Model NW-3
Sample Volume -- Ml
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
Lift in Feet

Figure 2

SERCO AUTOMATIC SAMPLER

Assembly for Model NW-3

1. The SERCO Automatic Sampler (Fig. 1) is shipped ready for operation except for placing the bottles in the trays. Be certain the numbers on the bottles correspond both to the tray numbers and the numbers on each switch.

2. Water may be visible in some of the bottles and tubes when the sampler is received. This is simply residual water left in the sampler after being tested prior to shipment. The water used is City of Minneapolis tap water.

3. To Remove Arbor Hub – See Figures 2 and 3
   a. Loosen and remove Knurled Screw (left hand thread).
   b. Remove Tripper Arm.
   c. Loosen allen head set screw (B) on side of Arbor Hub.
   d. Turn allen head screw (A) located in Arbor Hub below Knurled Screw. This will force hub off the tapered clock arbor.

4. To Install Arbor Hub – See Figures 2 and 3
   a. Unscrew allen head screws (A) and (B) a few turns.
   b. Place hub on clock arbor and tap gently to set in place.
   c. Turn allen head screw (A) into hub just until it is in contact with top of clock arbor.
   d. Tighten allen head screw (B) at side of Arbor Hub.

5. To Install Gear Head – See Figure 4
   a. Remove Arbor Hub (See instructions)
   b. Place Gear Head over arbor and rotate until ends of Gear Head are under the heads of the posts provided in top of clock housing.
   c. Install auxiliary strap to hold gear head in place.

Routine Operating Instructions for Model NW-3

See Figure 1 and 2

1. Be certain all bottles and tubing are clean.

2. Wind clock used to actuate switches. When using the clock in a room where the noise level is high and where the tick of the clock may not be heard, the motion of the main spring may be observed through the especially provided hole in the Switch Plate. This assures the user that the clock is running.

3. Set rubber stoppers securely in the 24 bottles.

4. Place Vacuum Head over Sampling Head and hold in place until it is vacuum sealed.

SERCO AUTOMATIC SAMPLER

5. Evacuate the system through the hose connection on the Vacuum Head using a vacuum source (such as a vacuum pump, vacuum system, or ejector). This can be done in the lab or in the field if a source of vacuum or power is available. A vacuum is assured in each bottle if each of the rubber tubes is collapsed (flattened.) The necessary vacuum to be maintained in the bottles in order to obtain a properly sized sample will vary with the conditions under which the sampler is used. See Table 1 for variation of sample size with sampling conditions.

6. Seal off each bottle by setting the switches on the Switch Plate.

7. Release the Vacuum Head and check to see if all bottles are evacuated and holding a vacuum. This may be easily done by observing the rubber tubes to see that each remains collapsed. As a precaution, the tubes to each bottle should be checked again at the installation site to be assured that bottles are still evacuated.

8. Set Tripping Arm to desired starting position. Be certain that the hole in the Tripping Arm fits snugly over the raised section at the top of the Arbor Hub and that the Knurled Screw is tightened securely. If Tripping Arm is not securely attached to Arbor Hub it will turn and not be capable of providing the torque to operate switches.
   Caution: Do not set Tripping Arm until you want to start sampling since the clock continues to run once it is started.

9. If you wish to cool the samples, place the ice containers in bottom of sampler by centering them in the painted square in sampler bottom.

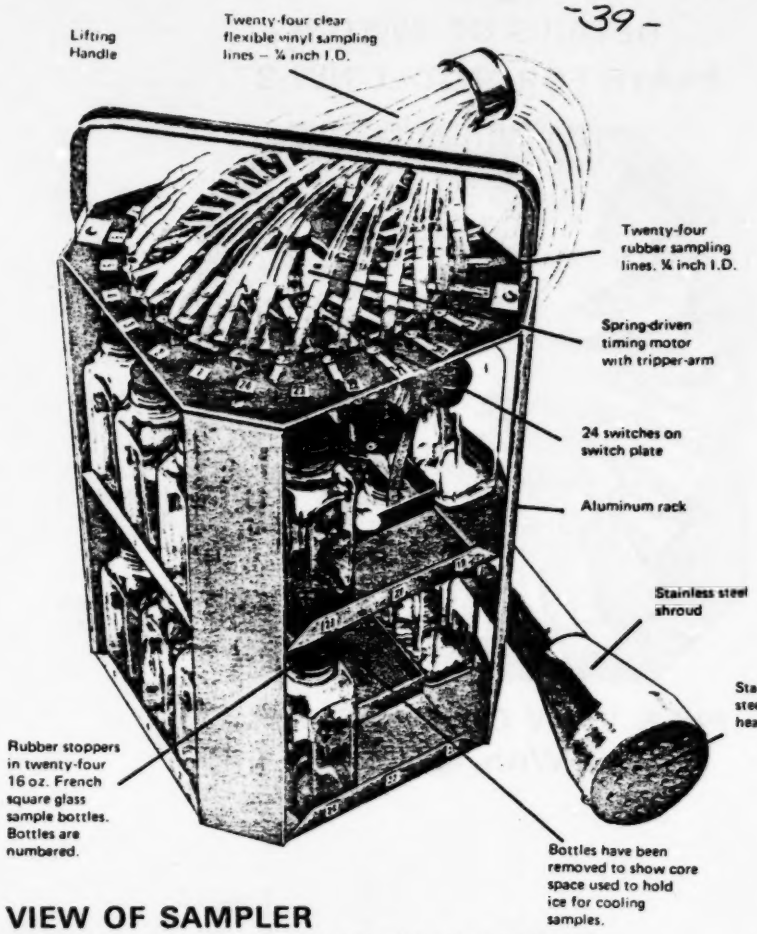
10. Lower rack into outer case.

11. Transport the sampler to point of use. Hang Sampling Head in the flow, and be sure it is low enough to obtain a sample when the flow level is at the minimum elevation.

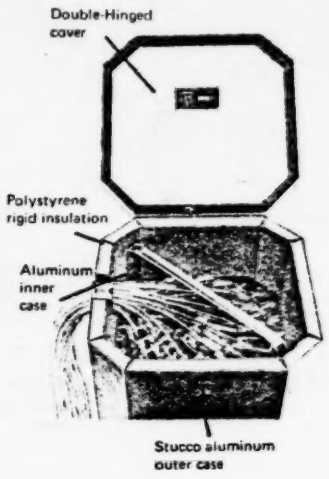
12. Record the bottle number of the first sample and the time sampling is started.

13. After sampling period, bottles may be removed and covered with caps and transported to a laboratory for analysis. Samples may be composited according to flow records and any one sample may be run individually. (Sample bottles may be left in sampler and entire unit transported to lab.)

14. Back flush each line with water (preferably hot, if available) from the rubber stopper end, and allow to dry for future use. Back flushing is best done with a piece of pipe or plastic tubing approximately 1/2-inch in diameter. With one end of this tube connected to a hose from the faucet, the other end may be pressed firmly against the rubber stopper to force water back through the sampling line. Also, the solids should be flushed from under Sampling Head Shroud.


Lifting Handle
Twenty-four clear flexible vinyl sampling lines – ¼ inch I.D.
Twenty-four rubber sampling lines, ¼ inch I.D.
Spring-driven timing motor with tripper-arm
24 switches on switch plate
Aluminum rack
Stainless steel shroud
Stainless steel sampling head
Rubber stoppers in twenty-four 16 oz. French square glass sample bottles. Bottles are numbered.
Bottles have been removed to show core space used to hold ice for cooling samples.

VIEW OF SAMPLER REMOVED FROM CASE: Model NW-3



VIEW OF SAMPLER IN POSITION FOR USE

Reproduced from best available copy.

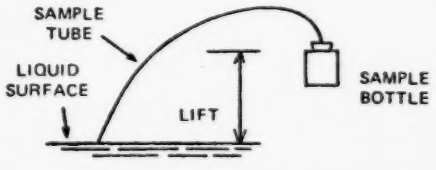
Figure 1

Table 1

APPROXIMATE VARIATION OF SAMPLE SIZE WITH CONDITIONS OF SAMPLING

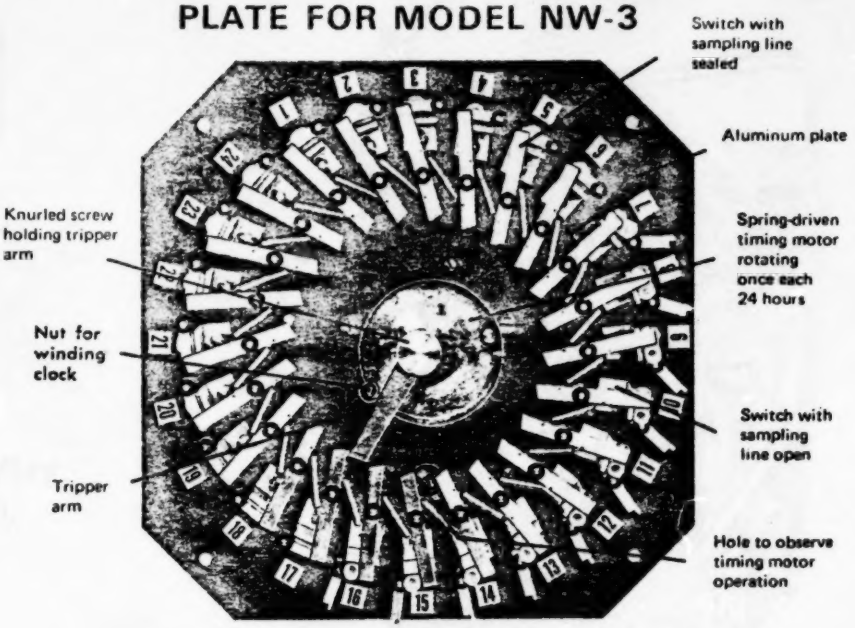
VACUUM GAGE READING IN. OF MERCURY	SAMPLE VOLUME Milliliters										ATMOSPHERIC PRESSURE IN. OF MERCURY
	26	24	22	20	18	16	14	12	10	8	
LIFT 3 FT.	370	333	295	259	221	184	147	110	74	36	30
		363	323	283	243	203	163	123	83	43	28
		400	356	312	268	222	178	134	90	46	26
			395	347	300	252	205	157	110	62	24
LIFT 8 FT.	282	237	193	149	105	61	27				30
		272	222	173	125	77	28				28
		310	257	204	150	97	43				26
			300	240	180	120	60				24
LIFT 13 FT.	153	97	43								30
		128	67	6							28
		167	97	27							26
			137	56							24

The size of the sample varies with the lift, the length and size of the sampling tube, the size of the sample bottle, the atmospheric pressure, and the vacuum held in the bottle. The values in the above table have been obtained with the equipment furnished with Serco Automatic Sampler Model NW-3.



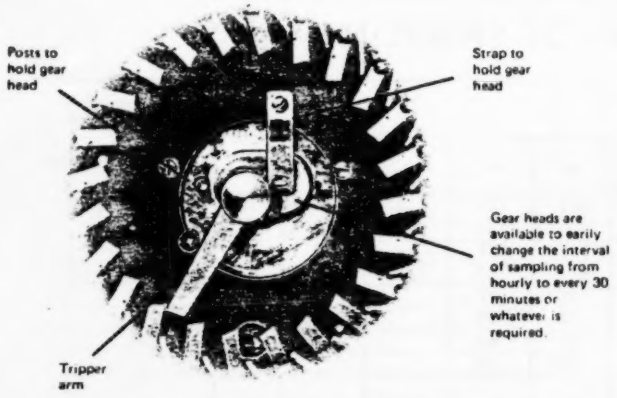
DETAILS OF SWITCH PLATE FOR MODEL NW-3

Figure 2


Switch with sampling line sealed
Aluminum plate
Spring-driven timing motor rotating once each 24 hours
Switch with sampling line open
Hole to observe timing motor operation
Knurled screw holding tripper arm
Nut for winding clock
Tripper arm

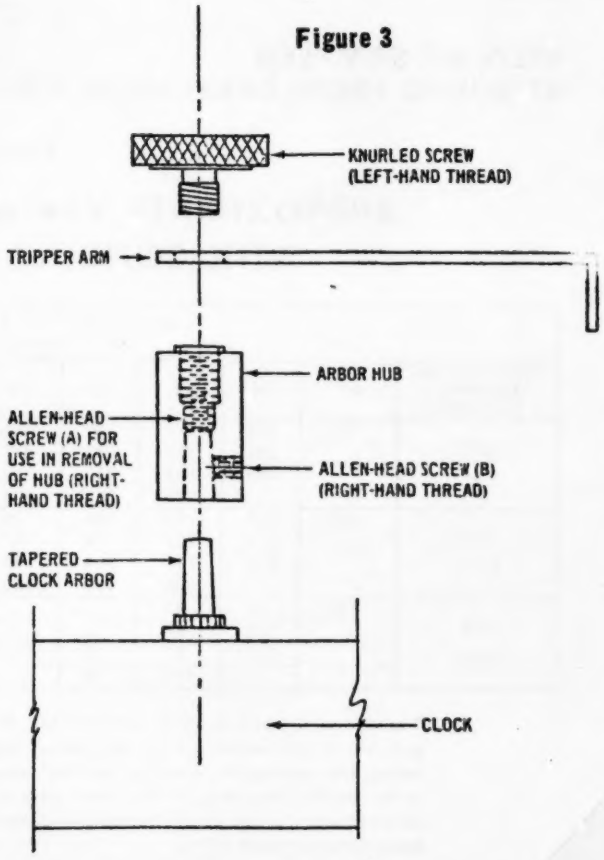
PLAN VIEW OF SWITCH PLATE (Shown With Tubes Cut Off)

Figure 4


Posts to hold gear head
Strap to hold gear head
Gear heads are available to easily change the interval of sampling from hourly to every 30 minutes or whatever is required.
Tripper arm

PLAN VIEW OF GEAR HEAD INSTALLED ON CLOCK

Figure 3


KNURLED SCREW (LEFT-HAND THREAD)
TRIPPER ARM
ARBOR HUB
ALLEN-HEAD SCREW (A) FOR USE IN REMOVAL OF HUB (RIGHT-HAND THREAD)
ALLEN-HEAD SCREW (B) (RIGHT-HAND THREAD)
TAPERED CLOCK ARBOR
CLOCK